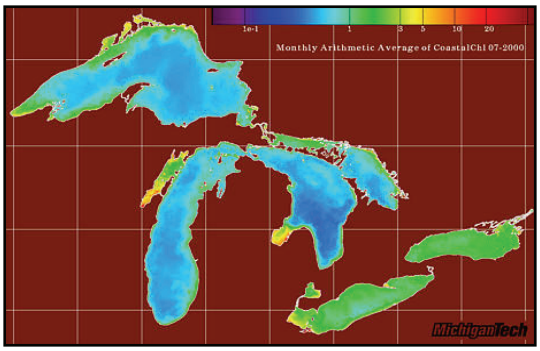
Harmful Algal Blooms and Hypoxia in the Great Lakes Region

Introduction

The Laurentian Great Lakes are a major resource to North America, containing 18% of the world's surface freshwater and 90% of the surface freshwater of the U.S. They serve as the focus for a multi-billion dollar tourist and recreation industry, supply 40 million people with drinking water, provide habitat for wildlife and fish, and support transportation and diverse agricultural production. The basin is home to 15% of the U.S. and 60% of the Canadian population.



The Problem

After a period of improving water quality during the 1980s and early 1990s, likely due to the phosphorus abatement programs that limited nutrients and reduced cyanobacterial (blue-green algae) blooms, harmful algal blooms (HABs), and low bottom water oxygen (hypoxia) have once again become important issues in the lower Great Lakes. Hypoxia has occurred frequently in the summer in western Lake Erie. HABs have been responsible for the closure of beaches, death of wildlife and contamination of drinking water supplies. HABs include cyanobacteria, especially *Microcystis*, which produce potent toxins that can contaminate drinking water and sometimes exceed safe drinking water guidelines, and macroalgae, such as *Cladophora*, that build up on beaches, impacting tourism and recreation. Although both HABs and hypoxia are naturally occurring they can also be promoted by human activities, especially those that affect nutrient availability. One potential cause for recent declines in water quality is the establishment of zebra mussels, a prolific invasive species which has fundamentally altered energy transfer and nutrient cycling.

Program Description

NOAA is conducting multidisciplinary and integrated programs to study HABs and hypoxia in the Great Lakes in order to identify the causes and develop solutions. Efforts combine monitoring and characterizing *Microcystis* blooms and the ecology and oceanography of HABs in the Great Lakes, along with ecological interactions with invasive species such as the zebra mussel. Research includes studies of the toxicity and bioaccumulation of microcystins in fish, identification, characterization and inventory of novel freshwater biotoxins, tier-based monitoring for toxic cyanobacteria in the lower Great Lakes, understanding the complex interactions between harmful phytoplankton and zebra mussel grazers and studies to forecast the susceptibility and species changes of the Great Lakes to future increases in nutrient loadings. In Lake Erie, NOAA's Center for Sponsored Coastal Ocean Research is funding the University of Michigan to develop models to forecast the causes and consequences of hypoxia and develop potential solutions. Also, NOAA's Great Lakes Environmental Research Laboratory recently led a multi-agency collaboration, the International Field Years on Lake Erie (IFYLE), to quantify the spatial extent of hypoxia across the lake, gather information that can forecast timing, duration, and extent and assess ecological consequences of hypoxia to the Lake Erie food web, including phytoplankton, bacteria, zooplankton and fish.

NOAA HAB and Hypoxia Programs in the Great Lakes Region

- ECOHAB
- Ecological Forecasting
- MERHAB
- IFYLE
- Marine Biotoxins
- CoastWatch

Accomplishments

In the early 1990's, NOAA made investments in the Great Lakes to develop an integrated Great Lakes Forecasting System which combines data from satellites, land, and lake-based systems with computer models for real-time prediction of the physical status of the Great Lakes. After undergoing 15 years of extensive development and testing, the system was completed and went operational in 2006 and provides output in the form of maps and data sets tailored to display specific information required by particular user groups. This system shows promise as an operational platform for HAB and hypoxia related tools and technology.

NOAA activities are also helping to evaluate the most cost effective "Alert" protocols to monitor for toxic cyanobacterial blooms and to improve identification and response to Freshwater HAB events. A team of NOAA-funded scientists are developing an integrated HAB alert system of detection methods which combines the application of satellite, conventional harmful algal bloom (HAB) detection methods, and novel quantitative molecular tools to detect, assess, predict, control, and mitigate HAB events. This practical, tiered alert approach to monitoring potentially toxic cyanobacterial blooms on Lake Erie will be refined and expanded upon over the next few years, incorporating advances in transport modeling that will allow predictions of bloom movement. Researchers are also coordinating with public health and water quality managers to raise awareness about toxic HAB impacts and the need for sustained HAB monitoring in the Great Lakes.

Additional NOAA activities are mapping the extent of hypoxia across Lake Erie; investigating the causes and consequences of hypoxia and forecasting predictions for the management of nutrient loading to minimize harmful phytoplankton problems in zebra mussel-invaded habitats; increasing general understanding of how nutrients and grazers interact to suppress or promote phytoplankton blooms, and identifying new and potentially dangerous biotoxins in the Great Lakes. NOAA and EPA are also currently undertaking a joint national assessment of freshwater HABs required by the Harmful Algal Bloom and Hypoxia Research and Control Act. This assessment will provide the framework for future HAB work in freshwater systems around the U.S. and in the Great Lakes.

Looking to the Future

The Great Lakes ecosystem is the most clearly definable regional ecosystem under NOAA's purview and mission responsibilities, contains a suite of environmental stresses common to all coastal systems, and has a long history of bi-national and interagency partnerships and collaborations. Thus, the Great Lakes have the greatest potential for success in testing regional approaches to addressing the problems of HABs and hypoxia and for the development of ecosystem forecasting tools to predict and help manage these stressors.

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NCCOS/CSCOR Activities in the Great Lakes

From 1990 to 2006 NCCOS' Center for Sponsored Coastal Ocean Research (CSCOR) provided approximately $11.5 M for activities in the Great Lakes. The following is a list of current and past funded projects.

RESEARCH PROJECTS

Ecological Forecasting (ECOFORE)

Forecasting the Causes, Consequences, and Potential Solutions for Hypoxia in Lake Erie (FY 2006-continuing). University of Michigan, NOAA Great Lakes Environmental Research Lab (GLERL), E2, Inc., LimnoTech, Inc., U. Wisconsin, Western Michigan U., Heidelberg College. Creating, testing and applying models to forecast how anthropogenic (land use, invasive species) and natural stresses (climatic variability) influence hypoxia formation and ecology in Lake Erie with and emphasis on fish production (FY 06: $419K)

Ecology and Oceanography of Harmful Algal Blooms (ECOHAB)

Investigating Chronic Toxicity and Bioaccumulation of Microcystins in Freshwater Fish Using Toxicogenomics and Histopathology (FY 2006-continuing). University of Tennessee. Investigating toxin concentrations that cause negative effects in fish during chronic low-level exposure and bioaccumulation. Determining, via biomarker gene expression, toxicogenetic and histopathological approaches that can be used in ecological forecasting of ecosystem health. (FY 06: $147K)

Complex Interactions Between Harmful Phytoplankton and Grazers: Variation in Zebra Mussel Effects Across Nutrient Gradients (FY 2004-continuing). Michigan State University, NOAA GLERL. Developing management protocols/practices to reduce effects of increasing cyanobacterial growth in zebra mussel-invaded lakes and to predict how future invaders (including exotic predators of zebra mussels) and changes in nutrient loading are going to impact harmful phytoplankton in the Great Lakes (FY 04-06: CSCOR $236K; EPA $450K)

Monitoring and Event Response for Harmful Algal Blooms (MERHAB)

Tier-Based Monitoring for Toxic Cyanobacteria in the Lower Great Lakes (FY 2002-continuing). SUNY College of Environmental Science and Forestry (ESF), SUNY at Brockport, SUNY at Buffalo, University of Tennessee, University of Vermont, Western Michigan University, New York Sea Grant. Developing an integrated alert system to monitor and detect toxic cyanobacteria blooms in the lower Great Lakes (Lake Erie, Lake Ontario) and Lake Champlain (FY 02-06: $3,622K).

Oceans and Human Health Initiative (OHHI)

Predicting Pathogen Fate in the Great Lakes Coastal Environment (FY 2005-continuing). Univ. of Wisconsin-Milwaukee, The Marshfield Clinic, NOAA GLERL. Determining the survival and physical transport processes that control dispersion and persistence of waterborne pathogens in the Great Lakes and develop better models predicting the fate of pathogens in aquatic systems (FY 05-06: $694K).

Identification, Characterization and Inventory of Novel Freshwater Biotoxins (2005-continuing). SUNY ESF, University of Tennessee. Determining the identity, distribution and occurrence on toxin-producing organisms and their toxins in Lake Erie (FY 05-06: $749K).

Episodic Events-Great Lakes Experiment (EEGLE)

Episodic Events-Great Lakes Experiment: The Impact of Episodic Events on the Nearshore-Offshore Transport and Transformation of Biogeochemically Important Materials in the Great Lakes (FY 1997-2002). Academy of Natural Sciences, Michigan Tech. U., NOAA/GLERL, Ohio State U., Rutgers U., SUNY/Buffalo, U. Georgia, U. Massachusetts U. Michigan, U. Minnesota, U. Texas, U. Wisconsin, U.

Southern Mississippi, USDA/ARS, USDOE/Argonne National Lab, USEPA, USGS, et al.. Created an integrated observational program and modeling effort to identify/develop prediction tools for the winter-spring sediment re-suspension event and to assess the impact of this event on the transport and transformation of biologically important materials and ecology of Lake Michigan (FY 97-02: $4,293K).

Great Lakes Forecast System

Great Lakes Forecast System Development (FY 1993-1996): NOAA GLERL, The Ohio State Univ., NOAA National Weather Service. CSCOR/COP funded the development of the now operational Great Lakes Forecast System (GLFS), a real-time coastal prediction system developed for forecasting wind-waves, surface water level fluctuations, and the horizontal/vertical structure of temperatures and currents. The NOAA Center for Operational Oceanographic Products and Services maintains GLFS in an 24-hour operational environment providing accurate information needed by a diverse user population utilizing the lakes (FY 93-96: $687K).

Great Lakes CoastWatch

Great Lakes CoastWatch Development (FY 1990-1994): NOAA GLERL, NOAA National Environmental Satellite Data and Information Service (NESDIS). CoastWatch is a nationwide NOAA program whose startup and development was funded by CSCOR/COP from FY 1990-94. NOAA GLERL functions as the Great Lakes regional node. NESDIS collects environmental data by NOAA satellites. CoastWatch processes this raw data and makes it available as ocean color, chlorophyll–*a* levels, and surface wind images. Resulting products are used in a variety of applications such as to predict weather, locate prime fishing areas, indicate harmful algal blooms, and for navigation (FY 90-94: $223K).

WORKSHOPS

Great Lakes Issue Identification Workshop (2003). NOAA CSCOR/COP, NOAA GLERL, Cooperative Institute for Limnology and Ecosystem Research. On Jan. 20-21, 2003 the NOAA CSCOR/COP funded and co-hosted a NOAA Great Lakes Issues Identification Workshop at the University of Michigan in Ann Arbor. The focus of this workshop was to identify major issues within the Great Lakes with the results of the workshop being a brief report of recommendations for future research efforts (FY 03: $9K)

Great Lakes Environmental Evaluation Training (1993-1997). NOAA Economics Group, U. Maryland Sea Grant, Northeast-Midwest Institute. Environmental valuation training was implemented to provide comprehensive information on the methods and applications of natural resource economic valuation to state/local planners, coastal zone/marine sanctuary managers, and natural resource trustees. Regional training workshops held around the country, including the Great Lakes (FY 97-98: $95K).

PUBLICATIONS

- Transport and Transformation of Biogeochemically Important Materials in Coastal Waters. 2004. *Journal of Geophysical Research* 109 (C10). ($24K)

- Special Issue on Lake Superior. *Journal of Great Lakes Research* 30(1): 1-491. ($10K)

- Revealing the Economic Value of Protecting the Great Lakes. 2001. The Northeast-Midwest Institute and the NOAA. 247 pp. (cost included in Great Lakes Environmental Evaluation Training above)

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